Study of Durability for Cement Concrete Pavement and Flexible Pavement in Expansive Soil Region

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Abstract: **In India more than 70% of the population lives in villages and their main source of livelihood is agriculture. Because of stringent environmental rules industries are now shifting towards villages. Both of these activities require a better means of communication which can be provided by good conditioned roads. Earlier village roads had low volume of traffic, consisting mostly of rural transport vehicles, like agricultural tractors/trailers, light goods vehicles, buses, animal drawn vehicles, motorized two-wheelers and cycles. Some of the rural roads used to have light and medium trucks carrying sugarcane, timber, quarry materials, etc. Kumar et al. (1998) presented a case study of Jaipur district of India regarding rural travel characteristics and highlighted the importance of the contribution of the access roads in rural development. As of now flexible pavements are preferred for village connectivity because of the type of traffic and low initial cost of construction. But due to high cost of maintenance, sensitivity to water logging and lack of institutional set up for the maintenance, village roads deteriorate very fast especially in Expansive soil regions. Every year their several kilometers are washed away by floods and water logging. Moreover, the nature of traffic is also changing due to industrial growth in the nearby areas. Rigid pavement is an alternative to flexible pavement where the soil strength is poor, aggregate are costly and the drainage conditions are bad (as in portions of the roads passing through villages and water logged areas). However, they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost. The guidelines have been developed by Indian Road Congress (1RC) for the design and construction of cement concrete pavements for village roads in year 2014, named as IRC: SP : 62 – 2014 However cement Concrete Pavements are also not a sustainable option in expansive soil Thus, the policy makers, planners and engineers are bound to think about a more suitable alternative pavement for rural roads in expansive soil.**

Index Terms–**Rigid pavements, Flexible pavements , Swelling and shrinkage property, CBR Value**

I. Introduction

One of the major indicators of a country's prosperity is its road length and vehicle Ownership India is a country where a large population live in villages with their livelihood depending upon agriculture. Industrial growth is also shifting towards villages. Both of these activities require a better means of communication which can be provided by good conditioned roads3% village roads have very low volume of traffic, consisting mostly of rural transport vehicles, like agricultural tractors/trailers, light goods vehicles, buses, animal drawn vehicles, motorized two-wheelers and cycles. Some of the village roads may also have light and medium trucks carrying sugarcane, timber, quarry materials, etc. flexible pavements are in use for village connectivity program because of low initial cost of construction to high cost of maintenance, being very sensitive to water logging and lack of institutional set up for their maintenance, the village roads deteriorate very fast, especially in expensive soil regions. Every year several kilometres of village roads are washed away by floods and water logging Thus, the planners and engineers are bound to think about the option of rigid pavement as a substitute of flexible pavement for village roads. Picture showing position of Sumerpur – Banki road of Sumerpur block, District - Hamirpur a newly constructed road got damaged with in the one year of its Construction. This road is constricted in year Oct – 2017 but get damaged within one year due to expansive soil.

Picture showing damage flexible pavement after one Rainy Season.

Sumerpur- Banki – Marg Distt- Hamirpur

Rigid pavement is an alternative to flexible pavement where the soil strength is poor, aggregate are costly and the drainage conditions are bad (as in portions of the roads passing through villages and water logged areas). However, they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost. The guidelines have been developed by Indian Road Congress (1RC) for the design and construction of cement concrete pavements for village road in year 2004, named as IRC: SP : 62 – 2004 which is now revised on 2014.

SP: 62-2004. For low traffic volume roads i.e. village roads and street rural road manual has been introduced by IRC where cement concrete roads are preferred in populated areas/streets to meet the problems of maintenance due to poor drainage etc. As most of – ocean plateau of India belong to expensive region having clay soil and poor drainage Conditions, lot of expenditure is being incurred every year to maintain the flexible pavements in their congenial condition and this necessitates the use of cement concrete road, a better option from climatic and environmental considerations.

The village roads have a very low volume of traffic consisting of tractors, animal drawn vehicles, light goods carriers, buses etc. The maintenance of village roads is constrained due to shortage of funds and poor institutional set up. These roads normally face problems of poor drainage condition, i.e. water logging besides poor strength of soil. Mostly flexible pavements with granular sub-base and base having thin bituminous carpet as wearing course are adopted, which deteriorate during long monsoon season leading to costly annual maintenance. This necessitates the exploration of other alternative pavements. Rigid pavements are one of the answers to this pertinent problem. However, they demand a high degree of professional expertise at the design stage, construction and maintenance besides high initial cost. In the present chapter a review of the rigid pavements alongwith the practices followed by Indian Roads Congress is presented.

Road pavements are generally designed to bear the loads imposed by traffic and stresses caused due to changes in environment such as temperature, moisture, etc. The pavement should be structurally sound and thickness of pavement should be sufficient enough to distribute the load and stresses uniformly to the subgrade. It should provide reasonably hard wearing surface to give smooth movement to the vehicles without any damage. Riding quality should also be good and the road should provide comfort and high speed to the users. Moreover, the pavement should be impervious so that water does not get into the subgrade and have long lasting life under low maintenance cost.

Three types of pavements: flexible, rigid and semi-rigid are generally used. Rigid pavements i.e. Cement Concrete pavements have numerous advantages over their flexible counterparts. In rigid pavements the slab acts as wearing surface and can be placed directly over subgrade but in case of weak soil, base course is provided. Surface course is the main structural part of the pavement that provides smooth and uniform surface to ride over it. It also prevents penetration of water into pavement and subgrade. Life of cement concrete road is much more than flexible pavements but initial cost of construction is high. Followings are the main types of rigid pavements in practice.

Flexible pavements – Now a days in Uttar Pradesh public work department flexible payment are usually constructed for village road and the most of the length of the village road are covered by these flexible pavements.

The design of flexible pavement is based on IRC SP – 2007 & 2015 these IRC code are widely used in construction of rural road in utter Pradesh by public works department and Central funded Pradhan mantri gram sadak yojana , it was widely used in Uttar Pradesh for design of flexible pavement for village road . The provisions of codes are as follows.

Estimation of traffic: Where no road is existing at present, the estimation of the amount of traffic over the design life cannot be made directly on the basis of traffic counts. In such cases, it would be most expedient to carry out traffic counts on an existing road, preferably in the vicinity with similar conditions. Based on such traffic counts on an existing road catering to a known population and known amount of agricultural/industrial produce, the amount of traffic expected to **ply** on the new proposed road can be suitably worked out.

The detailed procedure for estimating design traffic is described in Para3.

Assessment of subgrade strength: It is necessary to scientifically carry out a soil survey and test the representative samples for standard IS classification tests, compaction tests and CBR. The depth of Ground Water Table (GWT) and its fluctuations, annual rainfall, and other environmental conditions that influence the subgrade strength must be investigated. During the soil survey, it must be ensured that even if the same soil type continues, at least 3 samples must be collected per kilometer length, for simple soil classification tests. The entire length must be divided into uniform sections based on soil classification and Ground Water conditions. On each soil type, compaction and CBR tests shall lie carried out to determine the strength of subgrade soil for design purposes. A simple procedure for estimating CBR value of subgrade soil on the basis of soil properties is also suggested. The detailed procedure for assessing the CBR value for subgrade soil is described in Para 4.

Determination of pavement thickness and composition: It is necessary to carry out a comprehensive field materials survey and the needed laboratory tests on representative samples to maximize the use of locally available materials for use in sub-base, base and surface courses as such or after suitable blending. Using the design traffic parameter and the subgrade strength parameter, the pavement thickness and composition can be determined from the Design Catalogue given in Para 8. The total thickness requirement and also the thickness of various layers have been arrived at, keeping in view the main objective of maximizing the use of locally available materials. Where the CBR of subgrade soil is 2 or less, preferably improved subgrade soil should be used. The soil can be improved by mechanical stabilization or by modification with a suitable additive like lime, lime-flyash/cement etc.

TRAFFIC PARAMETER

Composition of Rural Traffic

It is not only the traffic volume but also its composition that plays an important role in determining the pavement thickness and composition (Ref. 6,11&17). There is a wide variety of vehicles plying on rural roads, half or even more of the total number being non-motorized, mostly bicycles and animal drawn carts. Among the motorized vehicles, the two-wheeled motor cycles constitute a sizable proportion followed by tractors/tractor-trailers, jugads, pick-up vans, jeeps and cars. Heavy Commercial Vehicles (HCV) like full-sized trucks and buses are relatively very few in number, their proportion out of the total may be as low as 5%, sometimes even lower. The number of Medium-heavy Commercial Vehicles (MCV) like tractor-trailers and medium-sized trucks is generally much higher than the number of HCV. Even though the number of animal drawn carts is on the decline, these are still sizable in number. The number of tractors/ tractor-trailers is gradually on the increase, while the number of motor cycles is increasing rapidly.

For purposes of pavement design, the large/ number of bicycles, motor cycles and pneumatictyred animal drawn carts are of little consequence and only the motorized commercial vehicles of gross laden weight of 3 tones and above (i.e. HCV and MCV) are to be considered.

A procedure has also been suggested to evaluate and consider the effect of Solid-Wheeled Carts (SWC) in computing the design traffic for pavement design.

Traffic Growth Rate

Some of the simple methods for estimating the traffic growth rates are given below:

Trend analysis: The past trend of growth is analyzed and the rate established by fitting a relationship of the type T_n = T0(1+r)" where n is the number of years, To is the traffic in zero year, T_n is the traffic in the year and r is the rate of growth in decimals. The future rate of growth can be fixed equal to or higher than the past rate depending on socio-economic considerations and future growth potential of the region where the road is located. Local enquiries in this regard are often very useful.

Design Life

While selecting the design life of a pavement it must be borne in mind that at the end of the design life, the pavement will not have to be reconstructed all over again. It only means that at the end of the design life, it will only need to be strengthened, so that it can continue to carry traffic satisfactorily for a further specified period. It is necessary to carry out proper condition surveys atleast once a year, so that the nature and rate of change of condition will help identify as to when the pavement will require strengthening. A design life of 10 years is recommended for purposes of pavement design for gravel roads (with periodic regravelling) and for flexible pavements. This design life period of 10 years has been recommended to ensure that neither the strengthening will need to be carried out too soon nor will the design for a very long design period be unduly expensive by way of high initial investment required.

Determination of ESAL applications: For purposes of Pavement Design, only commercial vehicles with a gross laden weight of 3 tons or more along with their axle loading are considered. These may include inter alia the following:

Trucks (Heavy, Medium) , Buses, Tractor-Trailers

The traffic parameter is generally evaluated in terms of a Standard Axle Load of 80 kN and the cumulative repetitions of the Equivalent Standard Axle Load (ESAL) are calculated over the design life.

Rural vehicles with single axle loads different from 80 kN, can be converted into standard axles using the Axle Equivalency Factor.

$$\text{Axle Equivalency Factor} = \left(\frac{W}{W_s}\right)^4$$

where W = Single axle load (in kN) of the rural vehicle in question

Ws = Standard Axle Load of 80 kN

Vehicle damage factor: The Vehicle Damage Factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions. It is defined as "equivalent number of standard axles per commercial vehicle". While the VDF value is arrived at from axle load surveys on the existing roads, the project size and traffic volume in the case of rural roads. may not warrant conducting an axle load survey. It may be adequate to adopt indicative VDF values discussed below for the purpose of pavement design.

For calculating the VDF, the following categories of vehicles may be considered:-

1. **Laden Heavy commercial vehicles (HCV)**

   Fully loaded HCV (comprising heavy trucks, full sized buses) have a Rear Axle load of 10.2 tonnes and a front Axle Load, about half the Rear Axle Load i.e. 5 tonnes. The VDF works out to 2.58 (=2.44+0.14)

2. **Unladen/Partially loaded Heavy commercial Vehicles.**

   Since the extent of loading of commercial vehicles is difficult to determine, a Rear Axle Load of 6 tonnes and a front axle load of 3 tonnes may be assumed for an Unladen/Partially Loaded HCV. The VDF works out to 0.31 (=0.29+0.02).

3. Overloaded Heavy Commercial Vehicles.

The extent of overloading may vary widely from one situation to the other. However, if only 10% of the laden HCV are overloaded to the extent of 20% the VDF works out to 2.86 (=0.9+2.58+0.1+5.35).

4. Laden Medium-heavy Commercial Vehicles (MCV)

Fully loaded MCV (mostly comprising Tractors-Trailers) have a Rear Axle Load of 6 tonnes and a front Axle Load of 3 tones. The VDF works out to 0.31 (=0.29+0.02).

5. Unladen/Partially loaded Medium-heavy commercial Vehicles

Since the extent of loading of commercial vehicles is difficult to determine, a Rear Axle load of 3 tonnes and a front Axle load of 1.5 tones may be assumed. The VDF works out to 0.019 (=0.018+0.001)

6. Overloaded Medium-heavy Commercial Vehicles

7. **The extent** of overloading may vary widely from one situation to the other. However, if an overload of 20% is there, . The VDF goes upto 0.65 (=0.61+0.04). If only 10% of the laden MCV are overloaded to the extent of 20%, the VDF = 0.344 (=0.1 x 0.65 + 0.9 x 0.31).

Towards the computation of ES AL applications, the indicative VDF values (i.e. Standard Axles per Commercial Vehicle) are given below:

Vehicle Type	Laden	Unladen/Partially Laden
HCV	**2.86**	**0.31**
MCV	0.34	**0.02**

Assuming a uniform traffic growth rate r of 6% over the design life (n) of 10 years, the cumulative ESAL applications (N) over the design life can be computed using the following formula:-

$$N = T_0 \times 365 \times \left[\frac{(1+0.01r)^n - 1}{0.01r}\right] \times L$$

$$= T_0 \times 365 \times \left[\frac{(1+0.06)^{10} - 1}{0.06}\right] \times L$$

$$= T_0 \times 4811 \times L$$

where T_0 = ESAL per day = number of commercial vehicles per day in the year of opening × VDF

and L = lane distribution factor; L = 1 for single lane/intermediate lane

and L = 0.75 for two-lane roads

Traffic Categories: For pavement design, the traffic has been categorized into seven categories as under:

Traffic Category	Cumulative ESAL Applications
T_1	10000-30000
T_2	30000-60000
T_3	60000-100000
T_4	100000-200000
T_5	200000-300000
T_6	300000-600000
T_7	600000-1000000

SUBGRADE STRENGTH EVALUATION

The Subgrade

Definition: As per MORD Specifications for Rural Roads (Ref 14), subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness, just beneath the pavement crust, providing a suitable foundation for the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment. In cuttings, the cut formation, which serves as the subgrade, is treated similarly to provide a suitable foundation for the pavement. Where the naturally occurring local subgrade soils have poor engineering properties and low strength in terms of CBR, for example in Black Cotton soil areas, improved subgrades: 1FC provided by way of lime/cement treatment or by mechanical stabilization and other similar techniques.

Subgrade Strength Classes

In order to use the Design Catalogue (Para 8), the subgrade strength is divided into the following classes:

Quality of Subgrade	Class .	Range (CBR%)
Very Poor	Si	2
Poor	**S2**	3 — 4
Fair	**S3**	5 — 6
Good	S_4	7 — 9
Very Good	S_5	10 —15

Where the CBR of subgrade soil is less than 2, t ie economic feasibility of replacing 300 mm subgrade with suitable soil needs to be explored and, if found feasible, the pavement should then be designed based on the CBR value of the improved subgrade. Alternatively, a capping layer of thickness not less than 100 mm of modified soil (with CBR not less than 10) should be provided.

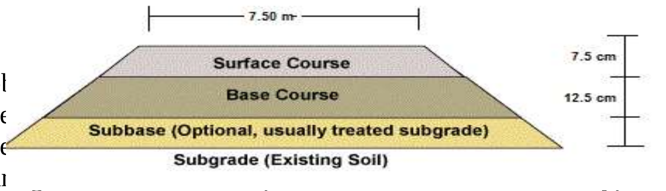
Pavement Composition

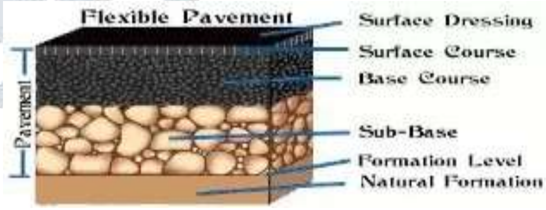
Sub-base course: For granular sub-base, the materials generally used are natural sand, moorum, gravel, crushed stone, crushed slag, brick metal, kankar or combination thereof depending upon the grading required as per Clause 401 of the MORD Specifications for Rural Roads (Ref 14). For silty clays and clayey soils including Black-Cotton soils, a lime treated subbase may be provided as per Clause 403 of the MORD Specifications for Rural Roads (Ref 14), taking care that the lime shall have purity of not less than 70% by weight of quicklime (Ca0) when tested in accordance with IS 1514. Where the lime of different calcium oxide content is to be used, its quantity should be suitably adjusted so that equivalent calcium oxide content is incorporated in the work. For soils which do not respond to lime treatment and where comparatively higher and faster development of strength and durability characteristics are needed, especially for waterlogged and high rainfall areas, cement treated subbase course can be provided, as per Clause 404 of the MORD Specifications for Rural Roads (Ref 14). The cement content for a cement treated subbase should be determined by mix design, yielding a 7-day unconfined compressive strength of not less than 1.7 MPa. From practical considerations, the thickness of subbase, where provided, shall not be less than 100 rnm.

Base course: For rural roads designed for cumulative ESAL repetitions more than 1,00,000, unbound granular bases which comprise conventional Water Bound Macadam (WBM), Wet Mix Macadam (WMM) or Crusher Run Macadam Base (CRMB) are adopted as per Clauses 405, 406 and 411 of the MORD Specifications for Rural Roads (Ref 14). Where hard stone metal is not available within economical leads, a cement stabilized base can be provided as per Clause 404 of the MORD Specifications for Rural Roads

For rural roads designed for cumulative ESAL repetitions less than 100,000, a Gravel base is recommended, except for a very poor subgrade strength (CBR=2) under the Traffic Categories of 30,000 to 60,000; and 60,000 to 100,000 ESAL applications and for poor subgrade strength (CBR=3 to 4) under the Traffic Category of 60,000 to 100,000 ESAL applications as shown in Fig. 4. The various grading, plasticity and other requirements for a Gravel base are detailed in Clause 402 of the MORD Specifications for Rural Roads.

Surfacing: For rural roads designed **for** cumulative ESAL repetitions, over 100,000, a bituminous surface treatment of 2-coat surface dressing or 20 mm premix carpet is recommended, as per MORD Specifications for Rural Roads (Ref 14). However, for rural roads designed for ESAL applications less than 100,000, a non-bituminous gravel surfacing is recommended as per Clause 402 of the MORD Specifications, except for the very poor subgrade strength (CBR=2) under traffic categories **T2** and **T3** and for the poor subgrade strength (CBR= 3 to 4) under Traffic Category **T3** only, where a bituminous surface treatment has been recommended,





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so a study over village roads in Uttar Pradesh clearly shows that flexible pavements in abadi portion cannot durable more than one year in abadi portion of the village road.

In expansive soil region flexible pavement get damage due to swelling and shrinkage property of black cotton soil. Soil Subgrade swell during winter or when moisture and shrink during summer proves & creaks in pavement Surface and under traffic flow body action and heavy pot holes developed in flexible pavement leads failure with in one to two year offer construction.

RIGID PAVEMENTS:

Considerable work has been carried out for the analysis, design and construction of rigid pavements by various researchers and design engineers. The guidelines have been developed by Indian Roads Congress for the design and construction of cement concrete pavements for village roads in year 2004, named as IRC: SP: 62-2004 which is further revised on 2014. For low traffic volume roads, i.e. village roads and streets, a rural road manual has been introduced by IRC, wherein it is mentioned to prefer cement concrete roads in populated areas/streets to meet out the problems of maintenance due to poor drainage etc. Cement Manufacturer Association of India and Prasad (2007) have shown that cement concrete rigid pavements are cheaper in terms of life cycle cost than flexible pavements. However, the initial construction cost of rigid pavements is much higher than the flexible pavements. Prasad (2007) carried out life cycle cost analysis of the two types of pavements and concluded that the cost difference between flexible and rigid pavement is negligible considering the savings for the cost of maintenance, vehicle operating cost and fuel. Further, rigid pavement is a better option from climatic and environmental considerations. Also, cement concrete pavement is the best option for locations having cement and fly ash in close proximity when sub-grade soils have low CBR values. A number of joints are provided in rigid pavements to reduce the stress due to change in temperature. Kadiyali and Dandvate (1984) made a comparative study of economics of rigid and flexible pavements and observed that the rigid pavement is far more economical than flexible one based on overall economic consideration. This generalization is valid for all zones of the country and is independent of the sub-grade characteristics.

Design of Cement Concrete Pavement As per IRC : SP- 62-2014 :
Wheel Load – 50 kN having a spacing of the wheels as 310 mm.
2. Tyre Pressure - Treck carrying dual wheel lood of 50 kN – 0.8 mpa , tractor – trailer – 0.50 mpa
3. Design Period - 20 years.
4. Design Traffic for Thickness Evaluation -
Traffic < 50 CVPD : only wheel lood stresses
Traffic 50 to 150 CVPD : stresses developed due to wheel load of 50 kN and temp diffevertial stresses
Traffic > 150 CVPD : fatigue can be real problem .

Temperature Variation between top and bottom of the slab in alluvialregion (IRC: SP 62-2014)

Zone	States	Temperature Differential °C in Slabs of Thickness		
		150 mm	200 mm	250 mm
i)	Punjab, Haryana, U.P., Uttranchal, Manipur, Meghalaya, Mizoram, Nagaland,Sikkim, Arunachal Pradesh, Tripura, Himachal Pradesh, Rajasthan, Gujarat and North M.P., excluding hilly regions	12.5	13.1	14.3
ii)	Bihar, Jharkhand, West Bengal, Assam and Eastern Orissa excluding hilly regions and coastal areas	15.6	16.4	16.6
iii)	Maharashtra, Karnataka, South M.P., Chhattisgarh Andhra Pradesh, Western Orissa and North Tamil Nadu excluding hilly regions and coastal areas	17.3	19.0	20.3
iv)	Kerala and South Tamil Nadu excluding hilly regions and coastal areas	15.0	16.4	17.6
v)	Coastal areas bounded by hills	14.6	15.8	16.2
vi)	Coastal areas unbounded by hills	15.5	17.0	19.0

Approximate k Value Corresponding to CBR Values

Soaked subgrade CBR	2	3	4	5	7	10	15	20	50
K Value (MPa/m)	21	28	35	42	48	50	62	69	140

Sub-Base

A good quality compacted foundation layer provided below a concrete pavement is commonly termed as subbase. It must be of good quality so as not to undergo large settlement under repeated wheel load to prevent cracking of slabs. The provision of a sub-base below the concrete pavement has many advantages such as:

i) It provides a uniform and reasonably firm support

ii) It supports the construction traffic even if the subgrade is wet

iii) It prevents mud-pumping of subgrade of clays and silts

iv) It acts as a leveling course on distorted, non-uniform and undulating sub-grade

v) It acts as a capillary cut-off

vi) Traffic up to 50 CVPD

vii) 75 mm thick compacted Water Bound Macadam Grade III (WBM III)/Wet Mix Macadam (WMM) may be provided over 100 mm granular subbase made up of gravel, murrum or river bed material with CBR not less than 30 percent, liquid limit less than 25 percent and Plasticity Index less (PI) less than 6. If aggregates are not available within a reasonable cost, 150 mm of cement/lime/lime-flyash treated marginal aggregate/soil layer with minimum Unconfined Strength (UCS) of 3 MPa at 7 days with cement or at 28 days with lime/lime-flyash may be used. The stabilized soil should not erode as determined from wetting and drying test (I RC:SP:89).

viii) Traffic from 50 to 150 CVPD

75 mm thick WBM lll/WMM layer over 100 mm of granular material may be used as a subbase. Alternatively, 100 mm thick cementitious granular layer with a minimum unconfined strength (UCS) of 3 MPa at 7days with cement or 28 days with lime/lime-flyash over 100 mm thick cementitious naturally available materials with a minimum UCS of 1.5 MPa with cement at 7 days or with lime or lime-flyash at 28 days may be provided.

ix) Traffic from 150 to 450 CVPD

x) 150 mm thick WBM III/WMM over 100 mm of granular subbase may also be used. Alternately, 100 mm of cementitious granular layer with a minimum UCS of 3.0 MPa at 7 days with cement or at 28 days with lime or lime-flyash over 100 mm of cementious layer with naturally occurring material with a minimum UCS of 1.5 MPa at 7 days with cement or at 28 days with lime or lime-flyash. Cementitious marginal aggregates may be much cheaper than WBMIWMM in many regions having acute scarcity of aggregates.

xi) The granular subbase and WBM layers should meet the requirement of MORD Specifications, Section 400(34). Quality of subbases varies from region to region and past experience on performance of concrete pavements in different regions is the best guide for the selection of the most appropriate subbases.

xii) Commercially available IRC accredited stabilizers with no harmful leachate also may be used if found successful on trials.

xiii) Effective modulus of subgrade reaction over granular and cement treated subbases

xiv) For the granular subbases, the effective k value may be taken as 20 percent more than the k value of the sub-grade shown in Table 3.1. For the cementitious subbases, the effective k value may be taken as twice that of the subgrade. Recommendations for estimated of effective modulus of subgrade reaction over granular or cemented subbase are given in Table 3.2. Reduction in stresses in the pavement slab due to higher subgrade CBR is marginal since only fourth root of k matters in stress computation but the loss of support due to erosion of the poor quality foundation below the pavement slab under wet condition may damage it seriously. The GSB layer with fines passing 75 micron sieve less than 2 percent can act as a good drainage layer and addition of 2 percent cement by weight of total aggregate will make it non-erodible. Most low volume roads with concrete pavements in built up area having WBM over GSB have performed well even under adverse drainage conditions.

xv) Effective k Values Over Granular and Cementitious Subbases

Soaked CBR	2	3	4	5	7	10	15	20	50
k Value over granular subbase (thickness 150 to 250 mm), MPa/m	25	34	42	50	58	60	74	83	170
k Value over 150 to 200 mm cementations sub base MPa/m	42	56	70	84	96	100	124	138	280

Adverse moisture condition leading to cracking of the unsupported concrete slab.

Concrete Strength

Since concrete pavements fail due to bending stresses, it is necessary that their design is based on the flexural strength of concrete. Where there are no facilities for determining the flexural strength, the mix design may be carried out using the compressive strength values and the following relationship:

$Ff = 0.7 \sqrt{fck}$

Where,

ff = flexural strength, MPa

fck = characteristic compressive cube strength, MPa

For Low volume roads, it is suggested that the 90 day strength may be used for design since concrete keeps on gaining strength with time. The 90 day flexural strength may be taken as 1.10 times the 28 day flexural strength or as determined from laboratory tests. 90 day compressive strength is 20 percent higher than the 28 day compressive strength. Heavy traffic may be allowed after

28 days. Pavement Thickness for Traffic up to 50 CVPD, A sub-base of 75 mm WBM over 100 mm GSB is considered. The subgrade soil has a CBR value of 4 Percent. The effective k value over WBM is taken as 42 MPaim (35 + 20 percent of 35 MPaim). Thickness values for a dual wheel load of 60 kN are 160 mm for all the joint spacing of 2.50 m, 3.25 m and 4.00 m since temperature stresses are not considered. For other k values, excel sheet can be used to get the thickness. A minimum thickness of 150 mm is recommended even for higher modulus of subgrade reaction. Pavement Thickness for Traffic from 50 to 150 CVPD Table 4.2 gives slab thickness for traffic from 50 to 150 CVPD. The thickness given in the table is applicable to common subgrade soils, such as, clay, silt and silty clay, with a CBR value of 4 percent. A sub-base of 75 mm WBM over 100 mm GSB is considered. The effective k value over WBM is taken as 42 MPa/m (35 + 20 percent of 35 MPa/m). Thickness values are indicated for joint spacing of 2.50 m, 3.25 m and 4.00 m.

Concrete Pavement Thickness for traffic between 50 and 150 CVPD and a Subgrade CBR of 4%

Joint Spacing in Metres	Pavement Thickness (mm)					
	Wheel Load-50 kN					
	Zone-I	Zone-II	Zone-Ill	Zone-IV	Zone-V	Zone-VI
4.00	180	180	190	180	180	180
3.25	170	170	170	170	170	170
2.50	160	160	160	160	160	160

Note : Design thickness values are based on the 90 day flexural strength.

Pavement Thickness for Traffic Greater than 150 CVPD

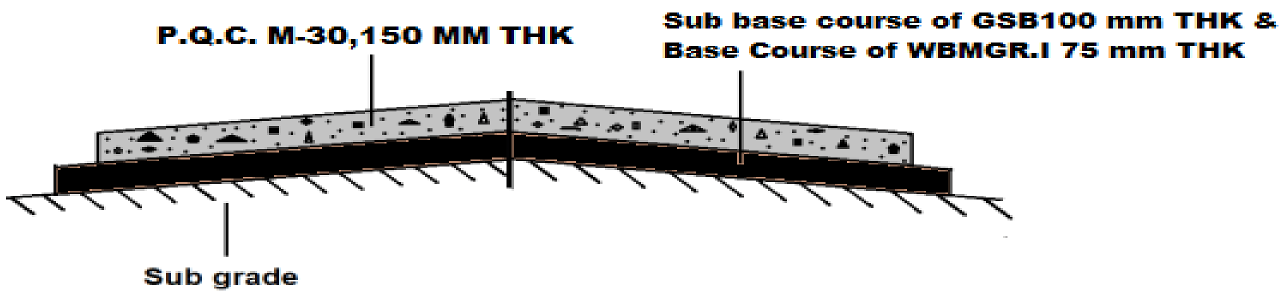
For traffic greater than 150 CVPD, fatigue also is to be considered and the thicknesses are shown in Table 4.3 for M30 concrete for a traffic of 250 CVPD having a subgrade CBR of 8 percent. It has a cementitious base with a total thickness of 200 mm. The effective k value for design is 100 MPafm (Table 3.2). Fatigue cracking of pavement slab is considered because of heavy traffic. Thicknesses for all six zones are given. Zone 3 has highest temperature differential and hence it gives the highest thickness because of higher curling stresses.

Concrete Pavement Thickness over for a Traffic of 250 CVPD

Thickness of cementitious subbase = 200 mm, (100 + 100) take k = 100 MPa (subgrade CBR = 8) Percentage of CVPD with 50 kN dual wheel load = 10

Joint Spacing M	Pavement Thickness (mm)					
	Wheel Load-50 kN					
	Zone-I	Zone-II	Zone-Ill	Zone-IV	Zone-V	Zone-VI
4.00	240	250	260	260	250	250
3.25	220	230	240	230	230	230
2.50	200	210	210	210	210	210

Most adopted c/s of rigid pavement by uttar Pradesh for village road



GSB Grade I – 100 MM THK
WBM Grade I – 75 MM THK
P.Q.C. (M-30)– 150 MM THK
U type or KC drain along both side of the road.

Sumerpur - Banki - Dharampur marg distt- Hamirpur (U.P.) cement concrete pavement in abadi portion

RESULT AND DISCUSSION

The plain cement concrete road pavement for rural roads designed on the basis of IRC: SP: 62-2004 requires minimum grade of concrete as M 30. The minimum thickness of pavement is also restricted to 150 mm. Spacing of contraction joints is limited to 4.5 further, IRC: SP: 62-2004 & 2014 specifies that rural road with dead end should be designed for 30 kN single wheel load with tyre pressure 0.5 Mpa and that the through rural roads for 51 kN single wheel load and tyre pressure 0.7 Mpa. The width of dead end road is limited to 3.0 m while through roads 3.75 m. The thicknesses of pavements as per design are 15.0 cm and 20.0 cm for dead end and through roads, respectively with M 30 concrete over 10 cm dry lean concrete. The design on the basis of IRC codes conservative and uneconomical because the stresses due to temperature variation are nonlinear. For the same configuration of variables design of flexible pavement has also been done which gives minimum thickness of 27.5 cm to 32.5cm. The cost for one kilometer flexible pavement has also been calculated and compared with the cost of one kilometer plain cement concrete pavement. Although, the initial cost of flexible pavement is lower than plain cement concrete pavement but from overall cost point of view and for the design life period, PCC pavements are economical. Therefore, adoption of rigid pavements for village roads in alluvial regions is a better option. By detail study and survey of all village roads constructed in expansive soil region it is found that flexible pavements are having durability max 1 to 2 years. Heavy pot holes body action developed during rainy season. Major maintenance required to repair such roads. White rigid pavement are having life up to 5 years but crocodiles cracks are seen in cement concrete pavements constructed in expansive soil region although the durability of rigid pavement is more than the flexible pavement but it is also not a sustainable option for village road in expansive soil region Thus, the policy makers, planners and engineers are bound to think about a more suitable alternative pavement for rural roads in expansive soil.

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